

REMARKS

Claims 1-3, 7-9, 11 and 13-29 are pending in the application. Claim 1 has been amended. Claims 4-6, 10 and 12 have been canceled. Claims 7 and 13-29 have been withdrawn from consideration. Claims 1-3, 8, 9 and 11 have been rejected.

Claims 1-3, 8, 9 and 11 have been rejected under 35 U.S.C. §112, first paragraph, for the reasons indicated on Page 2 and 3 of the Office Action. Specifically, the Examiner states that the copy of Hawley's Condensed Chemical Dictionary, Eleventh Edition 1987, challenging the definitions of "epoxide" and "epoxy resin" were not received, and further that The Handbook of Epoxy Resins on pages I-1 and I-2 clearly differentiates between monoepoxide compounds and an epoxy resin defined "as any molecule containing more than one α -epoxy group...capable of being converted to a useful thermoset form." Applicants respectfully traverse the rejection.

Applicants again attach for the Examiner's consideration a copy of the definitions of the terms "epoxide", "epoxy resin" and "resin" as they appear in Hawley's Condensed Chemical Dictionary, Twelfth Edition, 1993. Neither the definition of "epoxide" nor the definition of "epoxy resin" state that an epoxy resin must contain at least two epoxy groups.

Applicants also include herewith for the Examiner's consideration a copy of an excerpt from the Concise Encyclopedia of Chemical Technology, Kirk-Othmer, 4th Ed. 1999, in which an epoxy resin is described as being "characterized by the presence of a three-dimensional ring known as the epoxy, epoxide, oxirane, or ethoxyline group" (Emphasis added). There is no stated requirement for more than one epoxy group.

Further, the definition of epoxy resin to which the Examiner refers in The Handbook of Epoxy Resins specifically states that "For the purpose of this book, an epoxy resin is defined as any molecule containing more than one α -epoxy group..." (Emphasis added). Applicants submit that this limitation indicates that such definition is not a generally accepted definition in the art, and

that one skilled in the art would recognize that the term epoxy resin as recited in claims 1, 9 and 11 could include the epoxides octadecyleneoxide, epichlorohydrin, styrene oxide, vinylcyclohexene oxide and glycidyl methacrylate. Applicants respectfully request reconsideration and withdrawal of the rejection of claims 1-3, 8-9 and 11 under 35 U.S.C. §112, first paragraph.

Claims 1, 2, 4-6 and 8-12 have been rejected under 35 U.S.C. §103(a) as being unpatentable over US 4,500,660 to Minamisawa et al. (hereinafter "Minamisawa") and Japanese Patent No. 64- or 01-060679 (hereinafter "JP '679"). The Examiner states that Minamisawa sets forth nitrile rubbers having a Mooney viscosity of between 40 and 110 at 100°C such as a carboxyl-modified nitrile rubber wherein the nitrile rubber includes a copolymer of butadiene and acrylonitrile, and that it would have been obvious to formulate the composition of Minamisawa and JP '679 with a carboxyl-terminated butadiene-acrylonitrile copolymer having the Mooney viscosity disclosed in Minamisawa, thereby indicating a liquid state, in order to facilitate processability. Applicants respectfully traverse the rejection.

Claim 1 has been amended to recite that the reactive liquid polymer (b) comprising a carboxyl-terminated butadiene-acrylonitrile copolymer is liquid at ambient temperature. Both Minamisawa and JP '679 disclose a composition comprising Nipol 1072, which is a solid acrylonitrile copolymer containing carboxy groups. Additionally, Nipol 1042 and Nipol 1043 are also solids, as evidenced by the Zeon Safety Data Sheet, a copy of which is attached for the Examiner's convenience. The Mooney viscosities disclosed in Minamisawa are measured at 100°C (212°F). Applicants' reactive liquid polymer, on the other hand, is liquid at ambient temperature. The Examiner's attention in this regard is directed to the specification at Page 17, lines 9-11, where Applicants state that the curable composition is "combined by blending at ambient or slightly elevated temperatures." One skilled in the art reviewing the teachings of Minamisawa would be guided to heating the copolymer in order to obtain a liquid polymer having the Mooney viscosity disclosed.

Because neither Minimasawa nor JP '679 does not disclose, teach or suggest the curable composition claimed by Applicants, Applicants respectfully request the withdrawal of the rejection of claims 1-3, 8-9 and 11 under 35 U.S.C. §103(a).

Conclusion

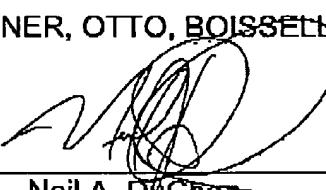
In view of the foregoing remarks and amendment, Applicants respectfully request reconsideration and a timely issuance of a notice of allowance for claims 1-3, 8-9 and 11. In the alternative, entry of the amendment is requested for purposes of an appeal

In the event any fees are due in connection with the filing of this document, the Commissioner is authorized to charge those fees to our Deposit Account No. 18-0988 under Attorney Docket No. BFGRP0313USB. In the event an extension of time is needed to make the filing of this paper timely and no separate petition is attached, please consider this a petition for the requisite extension and charge the fee to our Deposit Account No. 18-0988.

In the event there are issues the Examiner would like to discuss with the Applicants' attorney, he is invited to contact the undersigned by phone.

Respectfully submitted,

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By: 

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R/MTypak/GREP/BFGRP0313USB Response to Final

Safety Data Sheet 91/155/EEC (gb)**NBR-Nipol-Standard-Standard**

Zeon Chemicals Europe Ltd. GB- Sully, CF64 5YU



Revised: 12.09.2002

01. Identification of the substance / preparation and of the company			
Nipol 1000X 88	Nipol 1032	Nipol 1052-30	Nipol 35-5 SR
Nipol 1000X 132	Nipol 1032-45	Nipol 1053	Nipol 35-8
Nipol 1001CG	Nipol 1034-60	Nipol 1092-80	Nipol 40-5
Nipol 1001LG	Nipol 1041	Nipol 1094-80	Nipol HR 662
Nipol 1002	Nipol 1042	Nipol 30-5	Nipol HR 765
Nipol 1014	Nipol 1042X 82	Nipol 33-3	
Nipol 1022	Nipol 1043	Nipol 33-5 HM	
Nipol 1022X 59	Nipol 1051	Nipol 33-8 HM	
Nipol 1031	Nipol 1052	Nipol 35-5	

Use: Rubber products

Homepage: <http://www.zeon-europe.de>Company: Zeon Chemicals Europe Ltd,
South Glamorgan GB- Sully, CF64 5YU

eMail:

Fax: +44-1446-747 988

Phone: +44-1446-725 400

Emergency phone: +44-1446-725 400

02. Composition / Information on ingredients				
Substance	EINECS	CAS	Range [%]	Symbol / R-phr.
Acrylonitrile-Butadiene Polymer	9003-18-3		~100	
03. Hazards identification				
No particular hazards known.				
04. First-aid measures				
General information				
None.				
Inhalation				
Not applicable.				
Skin contact				
Consult a doctor if skin irritation persists.				
Eye contact				
Not applicable.				
Ingestion				
Not applicable.				
Advice to doctor				
Treat symptomatically.				
05. Fire-fighting measures				
Suitable extinguishing media				
Water spray jet. Dry powder. Foam.				
Extinguishing media that must not be used				
Full water jet. Carbon dioxide.				
Special exposure hazards arising from the substance or preparation itself or combustion products				
Risk of formation of toxic pyrolysis products.				
Special protective equipment for firefighters				
Use self-contained breathing apparatus.				
Additional information				
Fire residues and contaminated firefighting water must be disposed of in accordance with the local regulations.				
06. Accidental release measures				
Personal precautions				
Ensure adequate ventilation.				
Environmental precautions				

07. Handling and storage				
Advice on safe handling				
Use only in well-ventilated areas.				
Advice on protection against fire and explosion				
No special measures necessary.				
Requirements for storage rooms and vessels				
No special measures required.				
Advice on storage compatibility				
Do not store together with oxidizing agents.				
Further information on storage conditions				
Keep container in a well-ventilated place. Store in a dry place. Protect from light.				
08. Exposure controls / personal protection				
Additional advice on system design				
09. Physical and chemical properties				
Ingredients with occupational exposure limits to be monitored				
Not applicable.				
Respiratory protection				Not applicable.
Hand protection				Protective gloves.
Eye protection				Not applicable.
Skin protection				Not applicable.
General protective measures				
Avoid contact with eyes.				
Hygiene measures				
Wash hands before breaks and after work. Use barrier skin cream.				

Section	Text	Page
ChemieBüro D.G. Schröder Tel. (0049) 0941-566-398, Fax. (0049) 0941-566-994 www.chemieburo.de/ info@chemieburo.de		

Safety Data Sheet 91/155/EEC (gb)**NBR-Nipol-Standard-Standard****Zeon Chemicals Europe Ltd. GB- Sully, CF64 5YU****Revised: 12.09.2002****Special labelling for certain preparations****Not applicable.****National regulations****Not applicable.****16 Other informations****Regulatory Information**

- 91/155 (2001/58)
- 67/548 (2001/59)
- 1999/45 (2001/60)
- 81/689 (2001/118)
- 89/542
- ADR (23.07.01)
- IMDG-Code (30.Amdt.)
- IATA-DGR (2002)
- Classification according to VbF
- Water hazard class

Modified position:

01

Hawley's

Condensed Chemical

Dictionary

TWELFTH EDITION

Revised by

Richard J. Lewis, Sr.



VAN NOSTRAND REINHOLD COMPANY

New York

RESIST

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was soon followed by a petroleum-derived product called coumarone-indene, which did indeed have the properties of a resin. The first synthetic elastomer was polychloroprene (1931), originated by Nieuwland and later called neoprene. Since then many new types of synthetic polymers have been synthesized, perhaps the most sophisticated of which are nylon and its congeners (polyamides, by Carothers) and the inorganic silicone group (Kipping). Other important types are alkyls, acrylics, aminoplasts, polyvinyl halides, polyester, epoxies, and polyolefins.

In addition to their many applications in plastics, textiles and paints, special types of synthetic resins are useful as ion-exchange media.

See "Cumar." See also plastic, paint, fiber, film, elastomer.

Note: Because the term "resin" is so broadly used as to be almost meaningless, it would be desirable to restrict its application to natural organo-soluble, hydrocarbon-based products derived from trees and shrubs. But in view of the tendency of inappropriate terminology to "gel" irreversibly, it is a losing battle to attempt to replace "synthetic resin" with the more precise "synthetic polymer."

See also note under gum, natural.

resist. A material that will prevent the fixation of dye on a fiber, thus making color designs and pattern prints possible. The resist may act mechanically, as a wax, resin, or gel which prevents absorption of the dye, or its accompanying mordant. Citric acid, oxalic acid, and various alkalies are among the more common resists of the chemical type.

resistor composition. A specially treated semiconducting metal powder compounded with glass binders and temporary organic carriers. Can be applied to glass or ceramic surfaces by stenciling, spraying, brushing, or dipping; firing range 704-760°C. Compositions can be blended with members of the same series to produce intermediate resistance values. Fired resistors have good reproducibility, low temperature and voltage coefficients, and stability to abrasion, moisture, and relatively high (125°C) ambient temperature.

Use: To produce fired-on resistor components for electronic circuits.

"Resistor" [SCM]. TM for stabilized grades of copper powder assaying at greater than 99% copper with a density 8.9 and apparent density range of 2.0-3.5 g/cm³. Marketed in several grades of various particle sizes.

Use: Fabrication of porous bearings, sintered ferrous machine parts, catalysts, magnesium chloride cements, metal friction surfaces, electric brushes, electrical contacts, metallic paints.

resite. See C-stage resin.

resitol. See B-stage resin.

"Resmetal" [Borden]. TM for a resin-metal composition that when catalyzed converts to metal-like solid. Recommended for mold making, patching, forming, and general repair of metal surfaces and objects.

resol. See A-stage resin.

resolution. See resolving power.

resolving power. The extent to which a lens can distinguish small particles and minute distances, i.e., fine structure. The human eye can resolve objects of 1/250th inch (100 microns) in any dimension. The compound microscope has a resolving power of 0.5 micron; an electron microscope can resolve fine structure as small as 5 Å units, i.e., in the molecular range. Two factors determine resolving power; the wavelength of the radiation utilized and the focal depth of the lens. The resolving power of a microscope is much more important than its ability to magnify, for no magnification, however large, can add detail to an image that was not first discerned by the lens system.

See also optical microscope; electron microscope.

resonance. (1) In chemistry, resonance (or mesomerism) is a mathematical concept based on quantum mechanical considerations (i.e., the wave functions of electrons); it is used to describe or express the true chemical structure of certain compounds that cannot be accurately represented by any one valence-bond structure. It was originally applied to aromatic compounds such as benzene, for which there are many possible approximate structures, none of which is completely satisfactory.

See benzene.

The resonance concept indicates that the actual molecular structure lies somewhere between these various approximations, but is not capable of objective representation. This idea can be applied to any molecule, organic or inorganic, in which an electron pair bond is present. The term "resonance hybrid" denotes a molecule that has the property. Such molecules do not vibrate back and forth between two or more structures, nor are they isotopes or mixtures; the resonance phenomenon is rather an idealized expression of an actual molecule that cannot be accurately pictured by any graphic device.

(2) In the terminology of spectroscopy, resonance is the condition in which the energy state of the incident radiation is identical with that of the absorbing atoms, molecules, or other chemical entities. Resonance is applied in various

1001

RESIN, SYNTHETIC

clear reactor uranium-235 from each is formed in the accepted the spent fuel in is effected phosphate, pitation. The um are sent. The fission stored. An- pess, has been um; here the um isotopes, cause its plu- d not be used ever, suitable adiation haz- at require use mole-control le radioactive problem that ed. There are s operational in Europe.

technique of, and typ- sensitized pa- may be coated ad potential communica- d and surface and unusual

See octane

ment of rosin

O_2 . An al-

CH_3
 -OCH_3
 CH_3

ightly yellow- wly on expo- pidly in solu- y soluble in benzene; mp

Derivation: From *Rauwolfia serpentina*.

Grade: USP.

Hazard: Carcinogen in animals, potential cancer risk in humans.

Use: Antihypertensive agent, tranquilizer.

"Resicure" [Ozark-Mahoning]. TM for a series of epoxy curing agents.

residual oil. A liquid or semiliquid product resulting from the distillation of petroleum and containing largely asphaltic hydrocarbons. Also known as asphaltum oil, liquid asphalt, black oil, petroleum tailings, and residuum. Combustible.

Use: Roofing compounds, hot-melt adhesives, friction tape, sealants, heating oil for large buildings, factories, etc.

See also fuel oil.

Note: Gasoline of 94 octane can be produced from residual oil in a high-temperature catalytic process, thus increasing the yield of gasoline from a barrel of crude by 33% when full-scale production is achieved.

"Resimene" [Monsanto]. TM for melamine and ureaformaldehyde resins. Supplied in organic liquid solutions. The melamine is also available in water-alcohol solution and soluble spray-dry powders.

Use: Paint, varnish, lacquer for automobiles, machinery, appliances, construction; electronics, missiles; chemicals, pulp and paper.

resin. A semisolid or solid complex amorphous mix of organic compounds.

Properties: It has no definite melting point and no tendency to crystallize.

Derivation: Resins can be of animal, vegetable, or synthetic origin.

resinamine. $\text{C}_{15}\text{H}_{42}\text{N}_2\text{O}_3$. Alkaloid from certain species of *Rauwolfia*.

Properties: White or pale buff to cream-colored, odorless, crystalline powder; darkens slowly on exposure to light, more rapidly when in solution; partially soluble in organic solvents; insoluble in water; mp 238C (in vacuo).

Use: Medicine (antihypertensive).

resinate. A salt of the resin acids found in rosin.

They are mixtures rather than pure compounds.

Use: See soap (2).

"Resin C" [Allied-Signal]. TM for a neutral synthetic coal-tar resin of high styrene content.

Properties: Light color, mp 115-123C, d 1.05, mineral oil cloud point 130-150C.

Use: To impart alkali- and grease-resistance to floor tile.

resin, ion-exchange. See ion-exchange resin.

resin, liquid. An organic polymeric liquid that, when converted to its final state for use, becomes solid (ASTM), e.g., linseed oil, raw or heat-bodied (partially polymerized). See also drying oil; resinoid.

resin, natural. (1) Vegetable-derived, amorphous mixture of carboxylic acids, essential oils, and terpenes occurring as exudations on the bark of many varieties of trees and shrubs. They are combustible, electrically nonconductive, hard and glassy with conchooidal fracture when cold, and soft and sticky below the glass transition point. Most are soluble in alcohols, ethers and carbon disulfide, and insoluble in water. The best known of these are rosin and balsam, obtained from coniferous trees; these have a high acid content. Of more remote origin are such resins as kauri, congo, dammar, mastic, sandrac, and copal. Their use in varnishes, adhesives and printing inks is still considerable, though diminishing in favor of synthetic products. (2) Miscellaneous types. Shellac, obtained from the secretion of an Indian insect, is still in general use as a transparent coating. Amber is a hard, polymerized resin that occurs as a fossil. Ester gum is a modified rosin. Amorphous sulfur is considered an inorganic natural resin. Liquid resins, sometimes called resinoids, are represented by linseed and similar drying oils. See also gum, natural (note); resin, synthetic (note).

resinoid. Any thermosetting synthetic resin, either in its initial temporarily fusible state or its final infusible state (ASTM). Heat-bodied linseed oil, partially condensed phenol-formaldehyde and the like, are also considered resinoids.

resinol. A coal-tar distillation fraction containing phenols. It is the fraction soluble in benzene but insoluble in light petroleum, obtained by solvent extraction of low temperature tars or similar materials. Resinols are very sensitive to heat and oxidation.

resin, synthetic. A man-made high polymer resulting from a chemical reaction between two (or more) substances, usually with heat or a catalyst. This definition includes synthetic rubbers and silicones (elastomers), but excludes modified, water-soluble polymers (often called resins). A distinction should be made between a synthetic resin and a plastic, the former is the polymer itself, whereas the latter is the polymer plus such additives as filters, colorant, plasticizers, etc.

The first truly synthetic resin was developed by Baekeland in 1911 (phenol-formaldehyde). This

oxide.

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ances and gas storage vessels; adhesive for composites and for metals, glass, and ceramics; casting metal-forming tools and dies; encapsulation of electrical parts; filament-wound pipe and pressure vessels; floor surfacing and wall panels; neutron-shielding materials; cements and mortars; non-skid road surfacing; rigid foams; oil wells (to solidify sandy formations); matrix for stained-glass windows; low-temperature mortars.

EPR. Abbreviation for ethylene propylene rubber, also for electron paramagnetic resonance.

epsilon acid. (1-naphthylamine-3,8-disulfonic acid). $C_{10}H_7(NH_2)_2(SO_3H)_2$.

Properties: White, crystalline scales; soluble in hot water.

Derivation: Naphthalene-1,5- and 1,6-sulfonic acids are nitrated and reduced, giving 1-naphthylamine-3,8- and 4,8-disulfonic acids. Separation is effected by crystallizing out the acid sodium salts of 1-naphthylamine-3,8-disulfonic acid.

Use: Azo-dye intermediate.

Epsom salts. See magnesium sulfate.

EPT. Abbreviation for ethylene-propylene terpolymer.

"Eptac No.1" [Du Pont]. TM for zinc dimethylthiocarbamate, an ultra-accelerator for rubber.

"Eptam" [Stauffer]. TM for a selective herbicide containing ethyl-N,N-di-n-propylthiocarbamate.

EPTC. (S-ethyl di-N,N-propylthiocarbamate). CAS: 759-94-4. $C_2H_5SC(O)N(C_2H_5)_2$.

Available forms: Liquid and granular formulations.

Use: A pre-emergence herbicide.

eq. Abbreviation for gram equivalent weight, i.e., the equivalent weight in grams. Recommended as an international unit.

Equanil [Wyeth-Ayerst]. Proprietary name for improbamate.

Use: Sedative.

equation of state. The mathematical formula which expresses the relationships between pressure, volume, and temperature of a substance in any state of aggregation.

equilibrium. (1) Chemical equilibrium is a condition in which a reaction and its opposite or reverse reaction occur at the same rate, resulting in

a constant concentration of reactants; for example, ammonia synthesis is at equilibrium when ammonia molecules form and decomposes at equal velocities ($N_2 + 3H_2 \leftrightarrow 2NH_3$).

(2) Physical equilibrium is exhibited when two or more phases of a system are changing at the same rate so that the net change in the system is zero. An example is the liquid-to-vapor-vapor-to-liquid interchange in an enclosed system, which reaches equilibrium when the number of molecules leaving the liquid is equal to the number entering it.

equilibrium constant. A number that relates the concentrations of starting materials and products of a reversible chemical reaction to one another. For example, for a chemical reaction represented by the equation $aAB + bCD \leftrightarrow cAD + dBC$ the equilibrium constant would be $K = [(AD)^c (BC)^d] / [(AB)^a (CD)^b]$ where a , b , c , and d are the numbers of molecules of AB, CD, AD, and BC that occur in the balanced equation and (AD), (BC), (AB), and (CD) are the molecular concentrations of AD, BC, AB, and CD in any mixture that is at equilibrium. At any one temperature, K is usually at least approximately constant, regardless of the relative quantities of the several substances, so that when K is known it is often possible to predict the concentrations of the products when those of the starting materials are known. The constant changes markedly with temperature. The constant can often be calculated from the relations of thermodynamics if the free energy for the chemical reaction is known, or by measuring all concentrations in one or more carefully conducted experiments.

equilibrium diagram. (constitutional diagram).

(1) A simplified boiling-point diagram, showing for a liquid mixture the composition of the vapor in equilibrium with the liquid. (2) A chart showing the relation between a solution and the solids that may be crystallized from it. (3) A diagram showing the limits of composition and temperature in which the various phases or constituents of an alloy are stable.

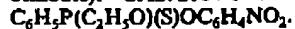
equipartition, law of. Every particle, heavy or light, gaseous or liquid, and independent of its chemical nature or form, always possesses the same mean energy of translation at a given temperature.

equipotential energy. The energy existing at a constant potential throughout a system.

equivalent electrons. Electrons of equal azimuthal quantum numbers and principal quantum numbers. They have identical orbital properties but may have a difference in sign of their orbital moments.

second crystal. This behavior is characteristic of some types of high polymers.

EPN. (o-ethyl-o,p-nitrophenyl phenylphosphorothioate). CAS: 2104-64-5.



Properties: Light yellow crystals, mp 36C, d 1.5978 (30C), insoluble in water, soluble in most organic solvents, decomposes in alkaline solutions.

Grade: Wettable powders and dusts.

Hazard: A cholinesterase inhibitor, absorbed by skin, use may be restricted. TLV: 0.5 mg/m³ of air.

Use: Cotton insect pest control, acaricide.

"Epolene" [Tennessee Eastman]. TM for a series of low-molecular-weight polyethylene resins. Available in both emulsifiable and non-emulsifiable types.

"Eponol" Resins. TM for high-molecular-weight linear copolymers of bisphenol A and epichlorohydrin; produce outstanding surface coatings by solvent evaporation alone.

"Epon" Resins [Shell]. TM for a series of condensation products of epichlorohydrin and bisphenol-A having excellent adhesion, strength, chemical resistance, and electrical properties when formulated into protective coatings, adhesives, and structural plastics.

"Epotuf" [Reichhold]. TM for epoxy resins, epoxy hardeners, and epoxy esters used as coating vehicles.

epoxidation. Reaction in which olefinic unsaturation is converted to a cyclic three-membered ether by active oxygen agents.

epoxide. An organic compound containing a reactive group resulting from the union of an oxygen atom with two other atoms (usually carbon) that are joined in some other way as indicated:



This group, commonly called "epoxy," characterizes the epoxy resins. Epichlorohydrin and ethylene oxide are well-known epoxides. The compounds are also being used in certain types of cellulose derivatives and fluorocarbons.

epoxidized linseed oil. See "Drapex" [Witco].

"Epoxybond" [Atlas]. TM for an epoxy adhesive putty in stick form.

1,2-epoxybutane. See 1,2-butylene oxide.

3,4-epoxyhexane carbonitrile.



Properties: Liquid, d 1.0929 (20/20C), bp 244.5C, fp -33C, soluble in water.

Hazard: Toxic by skin absorption, ingestion, and inhalation.

Use: Intermediate, stabilizer.

epoxyethane. See ethylene oxide.

2,3-epoxy-2-ethylhexanol.



Properties: Liquid, d 0.9517 (20/20C), bp (decomposes), fp -65C, slightly soluble in water.

Combustible.

Hazard: Skin irritant.

Use: Stabilizer, intermediate.

epoxy novolak. Epoxy resin made by the reaction of epichlorohydrin with a novolak resin (phenol-formaldehyde; see novolak). These have a repeating epoxide structure which offers better resistance to high temperatures than the epichlorohydrin-bisphenol A type, and are especially useful as adhesives.

2,3-epoxy-1-propanol. See glycidol.

epoxy resin. A thermosetting resin based on the reactivity of the epoxide group. One type is made from epichlorohydrin and bisphenol A. Aliphatic polyols such as glycerol may be used instead of the aromatic bisphenol A. Molecules of this type have glycidyl ether structures,

-OCH₂CHOCH₂, in the terminal positions, have many hydroxyl groups, and cure readily with amines.

Another type is made from polyolefins oxidized with peracetic acid. These have more epoxide groups, within the molecule as well as in terminal positions, and can be cured with anhydrides, but require high temperatures. Many modifications of both types are made commercially. Halogenated bisphenols can be used to add flame-retardant properties.

See also epoxy novolak.

The reactive epoxies form a tight cross-linked polymer network and are characterized by toughness, good adhesion, corrosive-chemical resistance, and good dielectric properties.

Most epoxy resins are the two-part type which harden when blended. A one-component liquid type for filament winding and a pelletized type for injection molding are available under the TM "Armax."

Hazard: Strong skin irritant in uncured state.

Use: Surface coatings, as on household appli-

KIRK-OTHMER

CONCISE ENCYCLOPEDIA
OF CHEMICAL TECHNOLOGY

4th EDITION



A WILEY-INTERSCIENCE PUBLICATION

John Wiley & Sons, Inc.

NEW YORK • CHICHESTER • WEINHEIM • BRISBANE • SINGAPORE • TORONTO

758 EPOXY RESINS

usually treated with an iv-administered pressor amine, including isoproterenol (beta agonist selective) NE, E, DA, and dobutamine. E is also the primary treatment for anaphylactic shock. E is commonly included in local anesthetic solutions to promote hemostasis, and by vasoconstriction to reduce absorption resulting in prolongation of anesthesia. Several related sympathomimetic vasoconstrictor amines (eg, phenylephrine hydrochloride) are used for nasal congestion. Because of their relaxation of bronchial smooth muscle, E and selected beta-2 agonists are used to antagonize the bronchospasm observed in asthma. NE is used for treating hypotension during anesthesia when tissue perfusion is good.

Alpha-adrenergic blocking agents such as prazosin (alpha-1 selective), which causes vasodilation in both arteries and veins without usually causing reflex tachycardia, are used to treat mild to moderate hypertension. Nonselective beta-adrenergic antagonists such as propranolol are used in the treatment of hypertension (usually with a diuretic), as prophylaxis in angina pectoris, and for prophylaxis of supraventricular and ventricular arrhythmias and other selected disorders. Selective beta-1 adrenergic antagonists such as metoprolol are used mainly for the treatment of hypertension. In addition, clonidine (an alpha-2 agonist) and methyldopa (metabolized to alpha-methylnorepinephrine in brain) act centrally on vasoconstrictor centers of the brain to reduce sympathetic outflow to the peripheral vessels and thus are used, but to a lesser extent, in the treatment of hypertension.

In Parkinson's disease, treatment with the amine precursor DOPA (with the decarboxylase inhibitor carbidopa), has been shown to ameliorate the symptoms and signs of the condition and prolong life.

There are several other disorders of the central nervous system in which catecholamines have been shown to be involved and drugs that affect the actions of catecholamines have a therapeutic action. Dopamine receptor antagonists that encompass several chemical classes such as phenothiazines (eg, chlorpromazine, butyrophenones (eg, haloperidol, and thiothixene derivatives (eg, chlorprothixene, are prescribed for the management of both acute and chronic psychoses and in nonpsychotic individuals who are delusional or excited (eg, mania). In the treatment of depression, most antidepressants are believed to improve mood by increasing catecholamine and/or serotonin concentrations.

Besides behavior and blood pressure, catecholamine neurons also have important roles in other brain functions. Regulation of neuroendocrine function is a well-known action of catecholamines; for example, DA agonists reduce serum prolactin concentration, especially in conditions of hypersecretion. Ingestive behavior can be modulated by brain catecholamines, and some appetite-suppressing drugs are believed to act via catecholaminergic influences. Catecholamines also participate in regulation of body temperature.

Toxicity

Untoward effects of both E and NE (usually to a lesser degree) are anxiety, headache, cerebral hemorrhage (from vasoconstrictor effects), cardiac arrhythmias, especially in presence of digitalis and certain anesthetic agents, and pulmonary edema as a result of pulmonary hypertension. The minimum subcutaneous lethal dose of E is about 4 mg, but recoveries have occurred after accidental overdosage with 16 mg subcutaneously and 30 mg intravenously, followed by immediate supportive treatment.

THOMAS A. PUCLSY
Warner-Lambert/Parke-Davis

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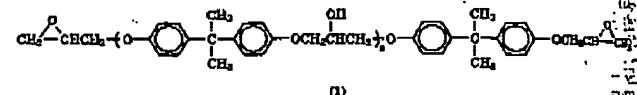
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EPOXY RESINS

Epoxy resins are characterized by the presence of a three-membered ring known as the epoxy, epoxide, oxirane, or ethoxyline group. Commercial epoxy resins contain aliphatic, cycloaliphatic, or aromatic backbones. The capability of the epoxy ring to react with a variety of substrates imparts versatility to the resins. Treatment with curing agents gives insoluble and intractable thermoset polymers. In order to facilitate processing and modify cured resin properties, other constituents may be included in the compositions: fillers, solvents, diluents, plasticizers, accelerators, curatives, and tougheners.

Resin Properties

Epichlorohydrin and Bisphenol A-Derived Resins. The most widely used epoxy resins are diglycidyl ethers of bisphenol A (1) derived from bisphenol A and epichlorohydrin.



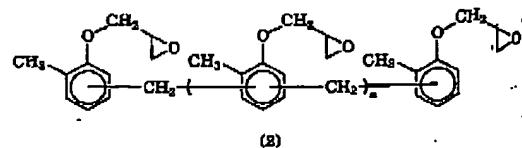
The outstanding performance characteristics of the resins are conveyed by the bisphenol A moiety (toughness, rigidity, and elevated temperature performance), the ether linkages (chemical resistance), and the hydroxyl and epoxy groups (adhesive properties and formulation latitude, or reactivity with a wide variety of chemical curing agents) (see also PHENOLIC RESINS).

The bisphenol A-derived epoxy resins are most frequently cured with anhydrides, aliphatic amines, or polyamides.

Diluents are commonly used to reduce the viscosity of epoxy systems to aid handling, improve ease of application, and to facilitate higher filler loading to reduce formulation cost. This, however, is achieved at the expense of other properties. To achieve a balanced properties, careful selection of diluent is needed.

Specialty Epoxy Resins. In addition to bisphenol, other polymers such as aliphatic glycols and novolaks are used to produce specialty resins. Epoxy resins may also include compounds based on aliphatic, cycloaliphatic, aromatic, and heterocyclic backbones. Glycidylation of active hydrogen-containing structures with epichlorohydrin or epoxidation of olefins with peracetic acid remain the important commercial procedures for introducing the oxirane group into various precursors of epoxy resins.

Epoxy Cresol-Novolak Resins (ECN). The cresol-novolak epoxy resins (2) are multifunctional, solid polymers characterized by low ionic and hydrolyzable chlorine impurities, high chemical resistance, and good thermal performance. ECN resins are widely used as major components in high performance electronic and structural molding compounds, high temperature adhesives, castings and laminates, systems, tooling applications, and powder coatings.



The epoxy cresol-novolak resins (2) are prepared by glycidylation of *o*-cresol-formaldehyde condensates in the same manner as the novolak resins.

Bisphenol F Resin. Bisphenol F epoxy resin is of the same structure as the epoxy phenol novolak. Bisphenol F is 2,2-methane bisphenol.

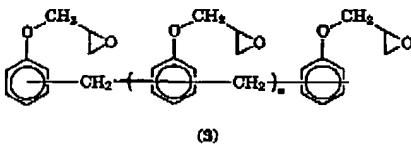
Owing to relatively low viscosity, these resins offer advantages of 100% solids (solvent-free) systems. Higher filler levels are possible because of the low viscosity. Faster bubble release is also achieved. Higher epoxy content and functionality of bisphenol F epoxy

can provide improved chemical resistance compared to conventional epoxies.

Bisphenol F epoxy resins are used in high-solids-high-build systems such as tank and pipe linings, industrial floors, road and bridge deck toppings, structural adhesives, grouts, coatings, and electrical varnishes. Bisphenol F epoxy resins are manufactured in Europe and Japan.

Epoxy Phenol-Novolak Resins. Epoxy phenol-novolak resins are represented by the general idealized structure (3) whereby multifunctional products are formed containing a phenolic hydroxyl group per phenyl ring in random para-para', ortho-para', and ortho-ortho' combinations.

Subsequent epoxidation with epichlorohydrin yields the highly functional epoxy novolak. The product can range from a high viscosity liquid of $n = 0.2$ to a solid of n value greater than 3.



The thermal stability of epoxy phenol-novolak resins is useful in adhesives, structural and electrical laminates, coatings, castings, and encapsulations for elevated temperature service. Filament-wound pipe and storage tanks, liners for pumps and other chemical process equipment, and corrosion-resistant coatings are typical applications using the chemically resistant properties of epoxy novolak resins.

Curing agents that give the optimum in elevated temperature properties for epoxy novolaks are those with good high temperature performance such as aromatic amines, catalytic curing agents, phenolics, and some anhydrides.

Polynuclear Phenol-Glycidyl Ether-Derived Resins. This is one of the first commercially available polyfunctional products. Its polyfunctionality permits upgrading of thermal stability, chemical resistance, and electrical and mechanical properties of bisphenol A-epoxy systems. It is used in molding compounds and adhesives.

Cycloaliphatic Epoxy Resins. This family of aliphatic, low viscosity epoxy resins consists of two principal varieties, cycloolefins epoxidized with peracetic acid and diglycidyl esters of cyclic dicarboxylic acids.

The nonaromatic nature of these materials provides for improved uv-resistance and arc-track resistance compared to conventional epoxies. The best properties are generally achieved with anhydride and phenolic curing agents.

Recommended applications include transformers, insulators, bushings, wire and cable coatings, generators, motors and switchgear, adhesives for adhesives, vinyl stabilization, and as viscosity depressants.

Aromatic and Heterocyclic Glycidyl Amine Resins. Among the specialty epoxy resins containing an aromatic amine backbone, the following are commercially significant.

Tetraglycidylmethylenedianiline-Derived Resins. Resins from aromatic glycidyl amines can be formulated into hot-melt or solution-binder systems with various reinforcements, eg, glass, graphite, boron, or aramid. They are utilized for graphite-reinforced composites in aerospace and leisure products, structural adhesives, laminates, tooling and casting applications, and structures such as wings and fuel tanks.

Triglycidyl p-Aminophenol-Derived Resins. Resins derived from triglycidyl p-aminophenol, originally developed by Union Carbide Corp., are currently marketed by CIBA-GEIGY. Synthesis is conducted by reaction of epichlorohydrin with the phenolic and amino groups followed by dehydrohalogenation. The product is a viscous liquid (1.5–5 Pa·s (15–50 P) at 25°C) which is considerably more reactive toward amines than standard bisphenol A-derived resins.

Used to increase heat resistance and cure speed of bisphenol A epoxy resins, it has utility in such diverse applications as adhesives, tooling compounds, and laminating systems.

Triazine-Based Resin. Triglycidyl isocyanurate is a solid resin that provides superior thermal, electrical, and mechanical properties and is recommended for laminates, insulating varnishes, coatings, and adhesives. Widely used as a curing agent for special polyester-based weatherable powder coatings, it is also used in electronic applications owing to its retention of optical transparency after aging at temperatures up to 150°C and minimal smoke evolution on thermal decomposition (see **EMBEDDING**).

The triazine ring-containing product 1,3,5-triglycidyl isocyanurate is synthesized by glycidylation of cyanuric acid with epichlorohydrin.

Resin Synthesis and Manufacture

Epichlorohydrin and Bisphenol A-Derived Resins. Liquid epoxy resins may be synthesized by a two-step reaction of an excess of epichlorohydrin to bisphenol A in the presence of an alkaline catalyst. The reaction consists initially in the formation of the dichlorohydrin of bisphenol A and further reaction by dehydrohalogenation of the intermediate product with a stoichiometric quantity of alkali.

In recent years, production of liquid resins of higher purity, ie, higher monomer content and fewer side-reactions, has been accomplished. This is in response to more stringent product quality requirements.

Aliphatic Glycidyl Ethers. Aliphatic epoxy resins have been synthesized by glycidylation of difunctional or polyfunctional polyols such as a 1,4-butanediol, 2,2-dimethyl-1,3-propanediol (neopentyl glycol), polypropylene glycols, glycerol, trimethylolpropane, and pentaerythritol.

The epoxidation is generally conducted in two steps: (1) the polyol is added to epichlorohydrin in the presence of a Lewis acid catalyst (stannic chloride, boron trifluoride) to produce the chlorohydrin intermediate, and (2) the intermediate is dehydrohalogenated with sodium hydroxide to yield the aliphatic glycidyl ether. Solid epoxy resins are prepared by the Taffy or Advancement processes.

Taffy Process. Bisphenol A reacts directly with epichlorohydrin in the presence of a stoichiometric amount of caustic. The molecular weight of the product is governed by the ratio of epichlorohydrin-bisphenol A. In practice, the taffy process is generally employed for only medium molecular-weight resins ($n = 1–4$).

Advancement Process. In the advancement process, sometimes referred to as the fusion method, liquid epoxy resin (crude diglycidyl ether of bisphenol A) is chain-extended with bisphenol A in the presence of a catalyst to yield higher polymerized products. The advancement process is more widely used in commercial practice.

In recent years, proprietary catalysts for advancement have been incorporated in precatalyzed liquid resins. Thus only the addition of bisphenol A is needed to produce solid epoxy resins. Use of the catalyst is claimed to provide resins free from branching which can occur in conventional fusion processes. Additionally, use of the catalyst results in rapid chain-extension reactions because of the high amount of heat generated in the processing.

The preparation of flame-retardant epoxy resins is accompanied by inclusion of tetrabromobisphenol A in the advancement process (see **FLAME RETARDANTS**). Products containing ca 20 wt % Br are extensively employed in the printed circuit board industry.

Liquid resins containing bromine (ca 49 wt %) can also be prepared directly from tetrabromobisphenol A and epichlorohydrin and are used for critical applications where a high degree of flame retardancy is required.

Curing Reactions

A variety of reagents has been described for converting the liquid and solid epoxy resins to the cured state, which is necessary for the development of the inherent properties of the resins. Liquid epoxy resins contain mainly epoxy groups and solid resins are composed of both epoxy and hydroxyl curing sites. The curing agents or hardeners are categorized as either catalytic or coreactive and the functional groups

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